Master of Science

Molecular Systems Science and Engineering

(MSSE)

Description of the course modules (Modulhandbook)

Heidelberg University

Faculty of Engineering Sciences

Key Information

Name of university	Heidelberg University
Name of department/Name of the Faculty	Institute for Molecular Systems Engineering and Advanced Materials (IMSEAM)/ Faculty of Engineering Sciences
Degree programme	Master of Molecular Systems Science and Engineering
Type of degree course	Consecutive
Acronym	MSSE
Formats of studies	Full time or part time
Standard period of study	2 years, i.e. 4 semesters
Total number of credit points	120
Location of studies	Heidelberg
Number of places in the programme	20
Target group	Holders of Bachelor of Science, Magister, Staatsexamen, Diploma or equivalent final degree of at least 6 semester study. Major in Physics, Chemistry, Materials Science, Molecular Biotechnology.
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1 Qualification objectives, profile and particularities of the degree program

1.1 Preamble – Qualification objectives of Heidelberg University

In keeping with Heidelberg University's mission statement and constitution, degree programs are designed to provide a comprehensive academic education, incorporating subject-specific, cross-disciplinary, and career-related objectives that prepare students for their future professional careers. The resulting skills profile is included in the course description for all university disciplines and is implemented in each degree program's specific qualification objectives, curricula, and modules.
The main points of the competence profile are:

- Development of subject-specific skills, with a particular emphasis on research,
- Development of the skills required for trans-disciplinary dialogue,
- Development of practical problem-solving skills,
- Development of personal and social skills,
- Promotion of students' willingness to assume social responsibility based on the skills acquired.

1.2 Profile of the MSSE

The research-oriented master program in Molecular Systems Science and Engineering (MSSE) at Heidelberg University is organized by the Institute of Molecular Systems Engineering and Advanced Materials (IMSEAM) and the Faculty of Engineering Sciences. Its educational objective is to deepen and broaden the student's expertise and prepare them for a research or development oriented professional career in the field of Molecular Systems Science and Engineering as well as for participation in PhD programs. The students develop a thorough understanding of various approaches and methods and are able to assess their advantages and drawbacks in order to develop the best solution for a given problem. They are able to realize which solutions are inappropriate or suboptimal and have the necessary skills to devise novel approaches. The MSSE program has a focus on practical skills. Students learn to work with state-of-the-art tools from molecular systems and materials research and are able to apply these skills to develop working solutions for application-oriented problems efficiently.
Students can choose three out of the five specializations *Energy Conversion, Molecular Design, Biomaterials, Nanosystems, Philosophy and Ethics in the Engineering Sciences*, which are sub-fields of 'Molecular Systems Science and Engineering'. Each specialization consists of a set of modules on an advanced level, which cover the field to a large extent. By following a sufficient number of modules in such a specialization, students reach the state-of-the art in the area to become fully competitive.
The master includes a research phase (2nd year), consisting of a seminar, a study project in the scientific specialization and the Master thesis, where students acquire the ability to do independent research and to document and publish their own research work. They deepen their knowledge on scientific methods, lab skills, entrepreneurship

and creativity, interdisciplinary system thinking, experience in practical applications as well as the communication competence and the ability to work in teams.

1.3 Subject-specific qualification objectives

After completing the master program ‘Molecular Systems Science and Engineering’, the obtained skills depend on the chosen specialization, as discussed in the description of the modules.

The MSSE program focuses on advanced research and prepares its students accordingly. Graduates will master various methods in chemistry, physics, biology, and engineering, applying them practically. The program emphasizes independent research, problem-solving, and effective project management through a thesis.

MSSE graduates excel in scientific communication, both written and oral, conveying their research effectively. They embrace self-directed learning, continuously acquiring knowledge and skills, and are skilled in gathering, analyzing, and interpreting information. Their ability to make informed decisions and articulate well-founded viewpoints sets them apart academically and professionally.

1.4 Generic qualification objectives

Graduates of the MSSE possess the skill to work independently with a variety of tools for various special applications and to choose the appropriate ones to solve specific problems in the field. They are able to work in a structured way and can organize complex professional projects. Additionally, they can acquire a basic understanding about legal and financial aspects of creating and running a company and are able to apply marketing strategies and tools.

MSSE graduates will possess the ability to formulate subject-specific perspectives and problem-solving strategies in molecular systems science and engineering. They will excel at articulating complex issues for both experts and non-specialists, defending their research findings, and working effectively in interdisciplinary teams. Graduates will also demonstrate strong leadership skills, inspire peers, and collaborate with people from diverse backgrounds to maximize team performance.

1.5 Employment Opportunities

Graduates having acquired competences in MSSE can for instance address challenges in the area of energy harvesting, biomaterials, nanosystems, and molecular engineering. Due to the broad course portfolio, graduates are interesting for employment in industry ranging chemical industry, energy technology companies, medical engineering to soft robotics, to name a few. Their interdisciplinarity makes graduates attractive for employment, as different subject specific cultures and terminologies have been trained, even in the direction of philosophy and ethics. Potential employers range from large companies, to start ups very specialized in the

field. Due to courses in entrepreneurship, IP, etc. It is also anticipated that graduates become active in these areas.

1.6 Particularities of the Degree Program

1.6.1 Reason for cumulative examinations

- The reason for the requirement of two examination components in one module is due to the fact that courses from different disciplines are to be chosen and that the competencies to be acquired vary considerably and cannot be properly tested in one examination.
- There are different examination formats intended in some modules (e.g. examination and written assignment) in order to check different skills. Furthermore, the curriculum offers a lot of choice with respect to the selection of seminar topics so that the acquired competencies can be assessed through several examinations - even if they have the same format, e.g. two written assignments on different topics.
- Since the competencies to be acquired in the modules are very heterogenic and differentiated, it is recommended that they are assessed in specific individual examinations instead of final module exams.

1.6.2 Teaching forms and assessment

In the MSSE, the following **teaching and learning forms** are predominantly used in the various courses:

- **Lecture:** Lecture by the lecturer, preparation and follow-up by self-study.
- **Lectures in the inverted classroom:** Self-study and guided consolidation and application of the material by the lecturer in the classroom.
- **Seminar:** Presentation of subjects by the students to other students and the lecturer.
- **Exercise/tutorial:** Based on the contents of the lecture, self-study, processing of exercise sheets, active questions and discussions.
- **Practical course/lab rotation:** Based on the contents of the lectures and/or coordination with the respective lab supervisor(s). Execution and evaluation of laboratory experiments, writing of experimental protocols.

Depending on the teaching form used, different assessment methods may be employed.

- **Theoretical course forms** (mainly lectures) are usually examined by written or oral exams. As a rule, this is done by written examinations of 90-180 minutes duration, or oral examination no longer than 60 minutes. Essays and project proposals are conceivable.
- **Seminars** are usually evaluated on the basis of the presentation given by the student and their active participation in the discussion, as well as prior preparation and review of provided materials.
- The performance assessment of **practicals** is usually based on a written protocol in the style of a scientific publication, the practical skills demonstrated

during the practical, prior preparation and review of provided material, as well as, if necessary, a presentation of the results. Depending on the preferences of the supervisors, not all examination methods may be required.

The concrete form of examination will be announced during the first session of the semester. Timely submission of written protocols, presentations, etc., is required.

1.6.3 Requirements for the assignment of credits

The final grade in the sections Research subject MSSE I, II, and III is determined by considering the weight of all required compulsory elective modules, which is based on the associated credit points (CP).

Composition of the final grade of the compulsory elective modules:

The final grade is determined by considering the weight of all courses, which is based on the associated credit points (CP).

2 Structure of the MSSE

2.1 Credit points (CP) and module types

The MSSE is structured into two categories: Compulsory modules and compulsory elective modules. For each module, a certain number of Credit Points (CP) is awarded upon completion, according to the rules of the European Credit Transfer and Accumulation System (ECTS). For graduation, a combined 120 CP are required.
The number of CP to be earned per module reflects the average student workload; 1 CP corresponds to approximately 30 hours of student work. This includes both the participation in the courses and the time required for preparation and follow-up of the course material (self-study).
How many CP are assigned to each module is specified in the respective module description. Students receive the credits as soon as the modules have been successfully completed, regardless of the grading of the performance. These points thus reflect the quantity of the performance rendered, whereas grades are assigned for qualitative assessment.

In this program, a distinction is made between a module and a course. Modules are self-contained teaching units that need to be completed in order to graduate. Some mandatory elective modules contain elective courses which can be chosen by the students. Courses can be lectures, seminars, or practicals. All modules are listed below.

2.2 Compulsory modules (84 CP)

All compulsory modules must be successfully completed in order to graduate. Students must not have lost their claim to be examined (Prüfungsanspruch) in any of the compuslory modules.
These modules aim to provide the students with the necessary knowledge to work in a research environment on their own projects under supervision.

The MSSE program contains these compulsory modules:

Compulsory modules	**84 CP**
Data and Project Management	6 CP
Creative Science Lab	12 CP
Technology Transfer	6 CP
Scientific Specialization	15 CP
Methods and Project Planning	15 CP
Master Thesis (including Colloquium)	30 CP

2.2.1 Data and Project Management

The "**Data and Project Management**" compulsory module covers three main topics: Project Management, Data Management, as well as Numerical Methods and Computation. Successful participation in and completion of this module are prerequisites for graduation.

Students will gain a comprehensive understanding of concepts of project management, including strategies relevant in business, but also in research. Data management has evolved as an essential strategy, particularly in interdisciplinary research labs and students will gain knowledge and experience in managing data, include data storage and metadata management. Furthermore, skills in numerical methods and computation will be acquired so that students develop awareness of the relevance of these methods and also their practical application, particularly in the context of MSSE.

2.2.2 Creative Science Lab (12 CP):

The **"Creative Science Lab"** compulsory module encompasses a six-week, hands-on laboratory practical and a seminar component. Successful participation in and completion of this module are prerequisites for graduation.

During this module, students will gain valuable skills for conducting thorough research and fostering independence within a laboratory environment. Additionally, they will build a solid foundation in various analytical, preparative, and theoretical methods applicable to molecular systems science and engineering. Students will nurture their ability to design experiments aimed at addressing scientific inquiries within this field and develop the skill to compare and evaluate different approaches to scientific questions.

2.2.3 Technology Transfer (6 CP)

The **"Technology Transfer"** compulsory module encompasses three main topics: Intellectual Property, Start-Ups, and Entrepreneurship. Successful participation in and completion of this module are prerequisites for graduation.

In this module students will acquire a comprehensive understanding of patenting strategies, encompassing the principles, processes, and intricacies involved in protecting intellectual property. They will not only be able to analyze but also critically evaluate the prerequisites necessary for securing and managing intellectual property rights effectively. In addition, students will gain a comprehensive grasp of the fundamental principles involved in establishing a successful startup business. This knowledge encompasses not only the core principles of entrepreneurship but also a deep understanding of business fundamentals. Additionally, students will develop a keen awareness of the entire process, starting from patenting their innovations and extending all the way to launching a startup venture. Students can propose their own ideas, prepare a business plan and pitch.

2.2.4 Scientific Specialization (15 CP):

The **"Scientific Specialization"** compulsory module encompasses a twelve-week, hands-on laboratory practical and a seminar component. Successful participation and completion of this module are prerequisites for admission to the Master Thesis and graduation.

Throughout this module, students will delve deeper into their chosen research subject, ideally equipping them with the knowledge and methodological experience needed for their Master thesis. Additionally, they will acquire further expertise in conducting research, including experiment development and evaluation, and gaining skills in communicating their research during regular lab meetings with their peers and members of their host lab.

2.2.5 Methods and Project Planning (15 CP):

The **"Methods and Project Planning"** compulsory module encompasses a twelve-week, hands-on laboratory practical and a seminar component. Successful participation and completion of this module are prerequisites for admission to the Master Thesis and graduation.

Throughout this module, students will delve deeper into their chosen research subject, ideally equipping them with the knowledge and methodological experience needed for their Master thesis. Additionally, they will acquire further expertise in conducting research, including experiment development and evaluation, and honing their skills in communicating their research findings during regular lab meetings with their colleagues in their host lab.

2.2.6 Master Thesis (30 CP, including Colloquium)

The **"Master Thesis"** compulsory module is scheduled for the fourth semester and involves a six-month, hands-on laboratory project where students will independently work on their own projects with guidance from their supervisor.

To begin the Master Thesis, students must have successfully completed the modules "Scientific Specialization" and "Methods and Project Planning."

The primary objective of the Master Thesis is to immerse students in the research environment and equip them with the skills necessary for a successful career in academia or industry.

2.3 Compulsory elective modules (36 CP)

The MSSE contains three sections of compulsory elective modules called Research Subject Molecular Systems Science and Engineering I, II, and III. Each section

requires a specific amount of compulsory elective modules to be completed successfully in order to graduate.
The goal of these modules is to equip students with essential knowledge, providing a robust foundation for becoming proficient and productive researchers. This knowledge is pivotal for both their research projects and effective collaboration with peers across diverse fields within Molecular Systems Science and Engineering. While the primary aim is to deepen expertise in their chosen areas of interest, these modules also offer the opportunity to expand horizons by exploring subjects beyond their core focus, all within the overarching framework of the field.

Section 1: Compulsory elective modules in Research Subject Molecular Systems Science and Engineering I	**18 CP**
Energy conversion	6 CP
Molecular Engineering	6 CP
Biomaterials	6 CP
Nanosystems	6 CP
Philosophy and Ethics in the Engineering Science	6 CP

Three of the **five** offered compulsory elective modules must be successfully completed in order to complete the section *Research Subject Molecular Systems Science and Engineering I*.

Section 2: Compulsory elective modules in Research Subject Molecular Systems Science and Engineering II	**6 CP**
Specialization (Macro)Molecular Engineering	6 CP
Specialization Life inspired molecular systems	6 CP
Specialization Physics of Functional Materials	6 CP
Specialization Physical and Biological Principles of Sensing	6 CP

One of the **four** offered compulsory elective modules must be successfully completed in order to complete the section *Research Subject Molecular Systems Science and Engineering II.*

Section 3: Compulsory elective modules in Research Subject Molecular Systems Science and Engineering I	**12 CP**
Functional Organic Materials	6 CP
Synthetic Biosystems	6 CP
Advanced Macromolecular Chemistry	6 CP
Physics of Molecular Systems Science and Engineering	6 CP

Two of the **four** offered compulsory elective modules must be successfully completed in order to complete the section *Research Subject Molecular Systems Science and Engineering III.*

2.3.1 Section: Research Subject Molecular Systems Science and Engineering I

The section "**Research Subject Molecular Systems Science and Engineering I**" encompasses five compulsory elective modules. Students must complete three of the five offered compulsory elective modules. Successful participation and completion of this section are prerequisites for graduation.

The five compulsory elective modules of this section are:

- Energy Conversion:
- Molecular Engineering
- Biomaterials
- Nanosystems
- Philosophy and Ethics in the Engineering Sciences

Energy Conversion: Students will develop a grasp of the core principles and regulations governing energy conversion. They will acquire the ability to employ these principles in practical calculations. Additionally, they will gain insight into the operational mechanisms of specific energy conversion tools and systems and will be capable of quantitatively assessing their performance attributes. Moreover, they will comprehend and be able to assess and discuss the requirements for materials utilized in energy conversion. Ultimately, students will be equipped with the necessary skills to apply these discussed concepts in fresh technological and societal scenarios.
Molecular Engineering: Students will gain an understanding of the general principles of molecular engineering, will have an overview of typical reactions, and common organic chemistry synthesis methods, and furthermore will be familiar with molecular characterization methods. In the end, they will be equipped with the necessary skills to apply these concepts in innovative technological and societal contexts.
Biomaterials: Students will grasp the fundamental principles of molecular engineering, get an overview of typical reactions and common organic chemistry synthesis methods, and become acquainted with various molecular characterization techniques. In the end, they will be equipped with the necessary skills to apply these concepts in innovative technological and societal contexts.
Nanosystems: Students will acquire the ability to distinguish various types of nanosystems and will be proficient in comparing their manufacturing processes. Additionally, they will be skilled at evaluating characterization methods for nanosystems and selecting appropriate strategies for them. Students will also possess practical knowledge of how to apply nanosystems and understand their functionalities. In the end, they will be equipped with the necessary skills to apply these concepts in innovative technological and societal contexts.
Philosophy and Ethics in the Engineering Sciences: Students will develop the ability to engage in discussions and comparisons regarding the questions and principles within the philosophy of science. They will also acquire the skills to address and compare ethical issues within the field of Molecular Systems Science and Engineering. In the end, they will be equipped with the necessary skills to apply these concepts in innovative technological and societal contexts.

2.3.2 Section: Research Subject Molecular Systems Science and Engineering II

The section "**Research Subject Molecular Systems Science and Engineering II**" encompasses four separate compulsory elective modules, each containing a wide selection of course (lectures, seminars, practicals). Students must complete one of the four offered compulsory elective modules. Successful participation and completion of this are prerequisites for graduation.

The four compulsory elective modules of this section are:

- Specialization (Macro)Molecular Engineering
- Specialization Life Inspired Molecular Systems
- Specialization Physics of Functional Materials
- Specialization Physical and Biological Principles of Sensing

Specialization (Macro)Molecular Engineering: Students will grasp the fundamental principles of macromolecules and polymers. They will also gain an overview of advanced synthesis techniques, properties, and characterization methods related to macromolecules. Moreover, they will become acquainted with the latest advancements in polymeric materials and their diverse applications.
Specialization Life Inspired Molecular Systems: Students exhibit a high level of expertise in various biomaterial classes and their corresponding properties. They possess the capability to scrutinize the mechanics of biomaterial systems and select appropriate testing methodologies. Furthermore, they have a solid grasp of how to integrate knowledge from disciplines such as biomedicine, biophysics, and biostatistics, effectively leveraging this multidisciplinary insight in their work.
Specialization Physics of Functional Materials: Students showcase an advanced level of knowledge and comprehension in the realm of advanced and functional engineering materials as well as the physical principles underlying these. They have the proficiency to employ principles from physics, chemistry, and materials science for articulating the characteristics of advanced and functional engineering materials. Additionally, they are well-versed in the latest innovations and breakthroughs within the field of advanced and functional engineering materials.
Specialization Physical and Biological Principles of Sensing: Students exhibit a high level of expertise in the field of information science. They possess the ability to analyze strategies within information sciences and computing, enabling them to comprehend and model molecular systems effectively. Moreover, they have a firm grasp of how to leverage knowledge from various disciplines, including mathematics, modeling, chemistry, and biology, to conduct research in the field of molecular systems.

2.3.3 Section: Research Subject Molecular Systems Science and Engineering III

The section "**Research Subject Molecular Systems Science and Engineering III**" encompasses four separate compulsory elective modules, each containing a wide selection of courses (lectures, seminars, practicals). Students must complete two of

the four offered compulsory elective modules. Successful participation and completion of this section are prerequisites for graduation.

The four compulsory elective modules of this section are:

- Functional Organic Materials
- Synthetic Biosystems
- Advanced Macromolecular Chemistry
- Physics of Molecular Systems Science and Engineering

Functional Organic Materials: Students will gain a solid grasp of the fundamental concepts that underlie the optoelectronic properties of organic (semi)conductors. They will also comprehend the operational mechanisms of common organic electronic devices. Additionally, students will be well-acquainted with recent experimental and theoretical findings, along with the methodologies employed to acquire them. Moreover, they will have the capability to apply these concepts in their own numerical experiments and when analyzing real experimental data.
Synthetic Biosystems: Students have the capability to articulate and make comparisons among various subjects within synthetic biology. They are also adept at scrutinizing experiments and theoretical concepts within the field of synthetic biology.
Advanced Macromolecular Chemistry: Students will grasp the chemical principles essential for designing, synthesizing, and developing macromolecules for practical real-world applications. They will have the capability to explain the processes of polymer synthesis and characterization, including an understanding of reaction mechanisms. Furthermore, they will attain a qualitative understanding of the resulting structures of macromolecules and will be proficient in determining their properties.
Physics of Molecular Systems Science and Engineering: Students will acquire advanced knowledge of the physical principles governing molecular systems. They will also develop a deeper understanding of the physical characterization of molecular systems and their fabrication techniques. Additionally, they will gain an overview of the various applications of molecular systems within the realm of the physical sciences.

2.4 Summary

In summary, the following modules must be completed successfully in order to reach the required 120 CP:

6/6 Compulsory Modules: Data and Project Management Creative Science Lab Technology Transfer Scientific Specialization Methods and Project Planning Master Thesis	**84 CP**
3/5 Compulsory Elective Modules in the section Research subject MSSE I Energy conversion Molecular Engineering Biomaterials	**18 CP**

Nanosystems Philosophy and Ethics in the Engineering Science	
1/4 Compulsory Elective Modules in the section Research subject MSSE II Specialization (Macro)Molecular Engineering Specialization Life Inspired Molecular Systems Specialization Physics of Functional Materials Specialization Physical and Biological Principles of Sensing	**6 CP**
2/4 Compulsory Elective Modules in the section Research subject MSSE III Functional Organic Materials Synthetic Biosystems Advanced Macromolecular Chemistry Physics of Molecular Systems Science and Engineering	**12 CP**
Sum	**120 CP**

2.5 Mobility Window

Students have the opportunity to participate in modules and internships at other universities in Germany and abroad, especially in the context of the Lab Rotations and the Master's thesis. This requires prior arrangement with the study coordinator. The second and third semesters are most appropriate for these endeavors.

2.6 Modules Overview and Relationships

The following table lists all compulsory modules and compulsory elective modules of the MSSE. Compulsory modules and sections are written in bold, compulsory elective modules are written in roman. The same module/course can not be counted twice.

CODE	Course Title	Recommended term	CP
MSSE_Core-I	**Section: Research subject Molecular Systems Science and Engineering I**	**1**	**18**
MSSE_EnCon	Energy Conversion	1	6
MSSE_MolEn	Molecular Engineering	1	6
MSSE_BioMat	Biomaterials	1	6
MSSE_NanoSys	Nanosystems	1	6
MSSE_PEES	Philosophy and Ethics in the Engineering Science	1	6
MSSE_DPMan	**Data and Project Management**	**1**	**6**
MSSE_Core-II	**Section: Research subject Molecular Systems Science and Engineering II**	**1**	**6**
MSSE_SpecMME	Specialization (Macro)Molecular Engineering	1	6

MSSE_SpecLIMS	Specialization Life Inspired Molecular Systems	1	6
MSSE_SpecPFMat	Specialization Physics of Functional Materials	1	6
MSSE_SpecPBPD	Specialization Physical and Biological Principles of Sensing	1	6
MSSE_CSLab	**Creative Science Lab**	**2**	**12**
MSSE_TechTrans	**Technology Transfer**	**2**	**6**
MSSE_Core-III	**Section: Research subject Molecular Systems Science and Engineering III**	**2**	**12**
MSSE_FOMat	Functional Organic Materials	2	6
MSSE_SBS	Synthetic Biosystems	2	6
MSSE_AdMaChem	Advanced Macromolecular Chemistry	2	6
MSSE_PMSSE	Physics of Molecular Systems Science and Engineering	2	6
MSSE_SciSpec	**Scientific Specialization**	**3**	**15**
MSSE_MPP	**Methods and Project Planning**	**3**	**15**
MSSE_MTC	**Master Thesis (including colloquium)**	**4**	**30**

3 Module descriptions

The following pages contain the descriptions of all modules offered primarily by the MSSE.

All compulsory modules and compulsory elective modules are offered and organized by the **I**nstitute for **M**olecular **S**ystems **E**ngineering and **A**dvanced **M**aterials (IMSEAM) (Im Neuenheimer Feld 225, 69120 Heidelberg).

Modules are open to non-MSSE students, as long as sufficient room space and infrastructure (e.g., lab space) area available. In seminars, the number of participants is limited by the time available for presentations. MSSE students are accepted with priority. Free slots are available for non-MSSE students. The lab practicals (Creative Science Lab, Scientific Specialization, Methods and Project Planning) and the Master Thesis are only intended for students of the MSSE.

An optional inclusion of modules in other study programs is left to these programs.

In the following module descriptions

- 'ST' is summer term ('Sommersemester'), lectures starting mid-April,
- 'WT' is winter term ('Wintersemester'), lectures starting mid-October.

3.1 Research subject Molecular Systems Science and Engineering I

CODE: **MSSE_Core-I**	TITLE: **Research subject Molecular Systems Science and Engineering I**
Type	Section with associated compulsory elective modules comprised of lectures and exercises.
Credit Points	18
Workload	540 hours
Term	WT
Section parts and teaching methods	• out of 5 possible compulsory elective modules (student's choice) • 3 lectures • 3 practical exercises with homework
Application of the section	Molecular Systems Science Engineering (Master of Science)

The section *Research subject Molecular Systems Science and Engineering I* consists of five compulsory elective modules. These are:

1. Energy Conversion
2. Molecular Engineering
3. Biomaterials
4. Nanosystems
5. Philosophy and Ethics in the Engineering Science

Three of the five compulsory elective modules in the section *Research subject Molecular Systems Science and Engineering I* must be completed successfully.

3.1.1 Energy Conversion

CODE: **MSSE_EnCon**	TITLE: **Energy Conversion**
Type	• Compulsory elective module of the section MSSE_Core-I • Lectures with exercise
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	• Lecture • Practical exercise with homework
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the compulsory elective module, the students will be able to… … understand the fundamental concepts and laws for energy conversion and can apply these in calculations. … understand the working mechanisms of selected energy conversion devices and systems and can quantitatively evaluate their performance characteristics. … understand and evaluate/discuss the demands on the materials used in energy conversion. … apply the concepts in novel technological and societal situations.
Content	• Types of energy • Thermodynamics • Energy in matter • Thermal energy conversion • Phase-change energy conversion • Solar energy and solar cells • Biological energy • Energy efficiency • Energy storage and batteries
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	• Written exam at the end of the semester. • Active participation in the exercises

3.1.2 Molecular Engineering

CODE: **MSSE_MolEn**	TITLE: **Molecular Engineering**
Type	• Compulsory elective module of the section MSSE_Core-I • Lectures with exercise
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	• Lecture • Practical exercise with homework
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the compulsory elective module, the students will be able to… … understand general principles in molecular engineering. … understand typical reactions, common organic chemistry, and synthesis methods. … understand molecular characterization methods. … apply their knowledge for independent solution of problems.
Content	• Introduction to molecular systems • Structure and reactivity: functional groups • Reaction mechanisms • Stereochemistry • Methods for molecular characterization • Applications
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	• Written exam at the end of the semester. • Active participation in the exercises

3.1.3 Biomaterials

CODE: MSSE_BioMat	TITLE: **Biomaterials**
Type	• Compulsory elective module of the section MSSE_Core-I • Lectures with exercise
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	• Lecture • Practical exercise with homework
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the compulsory elective module, the students will be able to… … describe biomaterial classes and properties. … analyze biomaterial mechanics systems and are able to choose a proper strategy. … discuss and review applications of biomaterials, particularly in the field of medicine. … discuss and review most recent inventions and developments in the field of biomaterials and their applications. … discuss and review advances in the research area of biomaterials in their respective societal context and approach ethical questions with the necessary nuance.
Content	• Introduction to living systems • Biomaterial classification • Material mechanics • Biocompatibility • Commercialization procedure of biomaterials • Applications of biomaterials (implants, biosensors, engineered systems) • Dynamic aspects in biomaterials science • Imaging methods • Engineered living materials • Basics of 3D printing • Ethical questions concerning (advances in) biomaterials
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	• Written exam at the end of the semester. • Active participation in the exercises

3.1.4 Nanosystems

CODE: MSSE_NanoSys	TITLE: **Nanosystems**
Type	• Compulsory elective module of the section MSSE_Core-I • Lectures with exercise
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	• Lecture • Lab • Seminar with homework
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the compulsory elective module, the students will be able to… … understand, evaluate and discuss properties of fluids at small scales. … understand, evaluate and discuss non-equilibrium active systems. … understand, evaluate and discuss optical properties of nanostructures. … understand, evaluate and discuss nanofabrication techniques, nanomaterials, DNA nanotechnology, nanomedicine and applications.
Content	• Properties of fluids at small scales: hydrodynamics, viscosity, Reynolds number, reciprocity, microfluidics, Brownian diffusion. • Non-equilibrium active systems: chemical motors, protein motors, active matter. • Optical properties of nanostructures: scattering, plasmonics, nanophotonics, synthesis of nanoparticles and quantum dots, characterization, and imaging methods. • Nanoscience: nanofabrication techniques, nanomaterials, DNA nanotechnology, nanomedicine, and applications
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	• Written exam at the end of the semester. • Successful participation in the exercises

3.1.5 Philosophy and Ethics in the Engineering Science

CODE: MSSE_PEES	TITLE: **Philosophy and Ethics in the Engineering Science**
Type	• Compulsory elective module of the section MSSE_Core-I • Lectures with exercise
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	• Lecture • Seminar
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the compulsory elective module, the students will be able to… … discuss and compare questions and principles of philosophy of science. … discuss and compare ethical concerns in Molecular Systems Science and Engineering.
Content	• Introduction to terms, concepts and aspects of philosophy and ethics • Introduction to philosophy of science • Introduction to ethics in the engineering sciences • Ethics in research, testing and industry • Current topics in the philosophy and ethics of engineering sciences
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	• Written exam at the end of the semester. • Successful participation in the exercises

3.2 Data and Project Management

CODE: MSSE_DPMan	TITLE: Data and Project Management
Type	Compulsory Module
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	Comprised of a mix of lectures, seminars, and self-studying modules
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to... … understand typical processes and methods of selected project management methods, as well as the underlying concepts. … demonstrate and evaluate basic skills in project planning, execution, and evaluation. … demonstrate and evaluate methods for conflict avoidance and mitigation in project management. … compare and identify advantages and drawbacks of various project management methods, including agile ones. … demonstrate advanced knowledge of research data management. … demonstrate and apply competencies on Metadata management. … demonstrate good practices when handling research data. … demonstrate advanced knowledge of numerical methods. … Demonstrate and evaluate basic programming strategies.
Content	• Terminology of project management • Processes, process models, agile and classical methods of project management, phase model • Project planning, execution, and evaluation • Conflict management, personality types and team roles • Findability, accessibility, interoperability, and reusability of data, metadata • Current principles of numerical methods • Programming and modelling software and principles
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	The exact type of examination will be announced at the beginning of the module by the lecturer(s)

3.3 Research subject Molecular Systems Science and Engineering II

CODE: **MSSE_Core-II**	TITLE: **Research subject Molecular Systems Science and Engineering II**
Type	• Section with associated compulsory elective modules • Dependent on student's course selection
Credit Points	6
Workload	180 hours
Term	WT
Section parts and teaching methods	• Choice between four compulsory elective modules and accompanying courses • Lectures, seminars, and practicals
Application of the section	Molecular Systems Science Engineering (Master of Science)

The section *Research subject Molecular Systems Science and Engineering II* consists of four compulsory elective modules. These are:

1. Specialization (Macro)Molecular Engineering
2. Specialization Life Inspired Molecular Systems
3. Specialization Physics of Functional Materials
4. Specialization Physical and Biological Principles of Sensing

One of the four compulsory elective modules from the section *Research subject Molecular Systems Science and Engineering II* must be completed successfully.

3.3.1 Specialization (Macro)Molecular Engineering

CODE: **MSSE_SpecMME**	TITLE: **Specialization (Macro)Molecular Engineering**
Type	• Compulsory elective module of the section MSSE_Core-II • Dependent on student's course selection
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	Students select lectures, seminars, and practicals to a total of 6 CP according to their preferences and availability.
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the compulsory elective module, the students will be able to… … understand the principles of macromolecules /polymers. … understand, evaluate and discuss advanced synthesis methods for macromolecules, properties and characterization. … understand, evaluate and discuss the most recent developments in the field of polymeric materials.
Content	• Introduction to macromolecules • Macromolecular synthesis • Characterization of macromolecules • Organic polymers • 3D printing of polymers
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	General Guidelines: • For lectures: Written exam at the end of the semester • For seminars: Presentation of a topic + participation in discussion • For practicals: Written lab report The type of examination will be announced at the beginning of the module by the lecturer(s).

3.3.2 Specialization Life Inspired Molecular Systems

CODE: **MSSE_SpecLIMS**	TITLE: **Specialization Life Inspired Molecular Systems**
Type	• Compulsory elective module of the section MSSE_Core-II • Dependent on student's course selection
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	Students select lectures, seminars, and practicals to a total of 6 CP according to their preferences and availability.
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the compulsory elective module, the students will be able to… … demonstrate advanced knowledge of biomaterial classes and properties. … analyze biomaterial mechanics systems and are able to choose a proper testing strategy. … understand and utilize knowledge from biomedicine, biophysics, biostatistics. … view advances in the research areas covered by life inspired molecular systems in their respective societal context and approach ethical questions with the necessary nuance.
Content	• Biological, physical, and chemical systems and networks • Bioinformatics • Biophysics • Modeling and machine learning • Ethical questions concerning (advances in) life inspired molecular systems
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	General Guidelines: • For lectures: Written exam at the end of the semester • For seminars: Presentation of a topic + participation in discussion • For practicals: Written lab report The type of examination will be announced at the beginning of the module by the lecturer(s).

3.3.3 Specialization Physics of Functional Materials

CODE: **MSSE_SpecPFMat**	TITLE: **Specialization Physics of Functional Materials**
Type	• Compulsory elective module of the section MSSE_Core-II • Dependent on student's course selection
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	Students select lectures, seminars, and practicals to a total of 6 CP according to their preferences and availability.
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the compulsory elective module, the students will be able to… … demonstrate advanced knowledge and understanding of advanced and functional engineering materials. … utilize concepts from physics, chemistry and materials science to describe advanced and functional engineering materials. … demonstrate familiarity with the most recent developments in the field of advanced and functional engineering materials.
Content	• Physical, chemical and biological materials, devices and systems • Mathematical concepts and modeling • Properties, tuning and applications of specific materials
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	General Guidelines: • For lectures: Written exam at the end of the semester • For seminars: Presentation of a topic + participation in discussion • For practicals: Written lab report The type of examination will be announced at the beginning of the module by the lecturer(s).

3.3.4 Specialization Physical and Biological Principles of Sensing

CODE: **MSSE_SpecPBPD**	TITLE: **Specialization Physical and Biological Principles of Sensing**
Type	• Compulsory elective module of the section MSSE_Core-II • Dependent on student's course selection
Credit Points	6
Workload	180 hours
Term	WT
Module parts and teaching methods	Students select lectures, seminars, and practicals to a total of 6 CP according to their preferences and availability.
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the compulsory elective module, the students will be able to… … demonstrate advanced knowledge of sensing principles and detection limits of natural and physical sensors: Biosensing, chemical sensing and physical sensors. … identify the underlying principles and determine the detection sensitivities. … understand utilize knowledge from mathematics, modelling, chemistry, physics and biology to analyze, design and quantify various sensors.
Content	• Senses in the natural world • Physics, chemistry of artificial sensors • Biosensors, physical sensors • Experimental principles
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	General Guidelines: • For lectures: Written exam at the end of the semester • For seminars: Presentation of a topic + participation in discussion • For practicals: Written lab report The type of examination will be announced at the beginning of the module by the lecturer(s).

3.4 Creative Science Lab

CODE: MSSE_CSLab	TITLE: **Creative Science Lab**
Type	• Compulsory module • 9-week lab practical
Credit Points	12
Workload	360 hours
Term	ST
Module parts and teaching methods	• In person lab practical, either centralized or in individual research groups • Seminar
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to… … perform proper research. … work in a research lab. … communicate in a scientific surrounding. … use the tools and conventions of science. … use scientific equipment correctly and safely. … design and carry out well-defined scientific experiments. … perform different analytical, preparative and/or theoretical methods relevant to molecular systems science and engineering. … choose the right methodologies for their respective scientific problems. … compare and rate different strategies to approach scientific questions.
Content	• Will be discussed with the supervisors individually • introduction to preparation, analyses and characterization methods in molecular systems science and engineering
Prerequisites	None
Recommended knowledge	Introductory courses to Physics/Chemistry
Requirements of the assignment of credits	• Lab report • Presentation in the seminar

3.5 Technology Transfer

CODE: MSSE_TechTrans	TITLE: Technology Transfer
Type	• Compulsory module • Lecture and seminar
Credit Points	6
Workload	180 hours
Term	ST
Module parts and teaching methods	Comprised of a lecture, seminar, and self-studying aspects
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to… … understand the principles of patenting strategies. … analyze and judge prerequisites for intellectual property. … understand the principles of creating a Start-Up business. … understand business basics. … understand the pipeline from patent to Start-Up. … understand the principles of entrepreneurship.
Content	• Introduction to intellectual property and patenting • Introduction to business basics • Introduction to Start-Up creation process
Prerequisites	None
Recommended knowledge	N/A
Requirements of the assignment of credits	• Seminar presentation of a topic • Participation in discussion • Written report/business plan proposal

3.6 Research subject Molecular Systems Science and Engineering III

CODE: MSSE_Core-III	TITLE: **Research subject Molecular Systems Science and Engineering III**
Type	• Section with associated compulsory elective modules • Dependent on student's course selection
Credit Points	12
Workload	360 hours
Term	ST
Section parts and teaching methods	• Choice between four compulsory elective modules and accompanying courses • Lectures, seminars, and practicals
Application of the section	Molecular Systems Science Engineering (Master of Science)

The section *Research subject Molecular Systems Science and Engineering III* consists of four compulsory elective modules. These are:

1. Functional Organic Materials
2. Synthetic Biosystems
3. Advanced Macromolecular Chemistry
4. Physics of Molecular Systems Science and Engineering

Two of the four compulsory elective modules from the section *Research subject Molecular Systems Science and Engineering III* must be completed successfully.

3.6.1 Functional Organic Materials

CODE: MSSE_FOMat	TITLE: **Functional Organic Materials**
Type	• Compulsory elective module of the section MSSE_Core-III • Dependent on student's course selection
Credit Points	6
Workload	180 hours
Term	ST
Module parts and teaching methods	Students select lectures and/or seminars to a total of 6 CP according to their preferences and availability.
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to… … understand the key concepts underlying the mechanical, electrical and optical properties of functional organic materials and their molecular basis. … demonstrate familiarity with the most relevant fabrication techniques including 3D printing. … understand the working mechanisms of typical devices based on functional organic materials. … demonstrate familiarity with recent experimental and theoretical results and the techniques used to obtain them.
Content	• Organic electronics • Synthesis, fabrication and 3D printing • Properties and applications of functional organic polymers and molecules
Prerequisites	None
Recommended knowledge	Introductory course to Solid State Physics
Requirements of the assignment of credits	• For lectures: Written exam at the end of the semester • For seminars: Presentation of a topic + participation in discussion • For practicals: Written report

3.6.2 Synthetic Biosystems

CODE: MSSE_SBS	TITLE: **Synthetic Biosystems**
Type	• Compulsory elective module of the section MSSE_Core-III • Dependent on student's course selection
Credit Points	6
Workload	180 hours
Term	ST
Module parts and teaching methods	Students select lectures and/or seminars to a total of 6 CP according to their preferences and availability.
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to… … describe and compare recent and advanced topics in synthetic biosystems. … analyze experiments and theoretical concepts in synthetic biosystems.
Content	• Introduction to synthetic biosystems • Experimental and theoretical methods in synthetic biosystems science • Fabrication methods to generate synthetic biosystems
Prerequisites	None
Recommended knowledge	Introductory courses to physics/chemistry and (ideally) biology/biomaterials
Requirements of the assignment of credits	• For lectures: Written exam at the end of the semester • For seminars: Presentation of a topic + participation in discussion • For practicals: Written report

3.6.3 Advanced Macromolecular Chemistry

CODE: MSSE_AdMaChem	TITLE: **Advanced Macromolecular Chemistry**
Type	• Compulsory elective module of the section MSSE_Core-III • Dependent on student's course selection
Credit Points	6
Workload	180 hours
Term	ST
Module parts and teaching methods	Students select lectures and/or seminars to a total of 6 CP according to their preferences and availability.
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to… … understand advanced methods for the synthesis of macromolecules. … understand the intricacies of advanced macromolecular characterization techniques. … demonstrate a broad understanding of the different applications of functional polymers.
Content	• Advanced macromolecular synthesis • Advanced characterization of macromolecules • Functional organic polymers • Applications
Prerequisites	None
Recommended knowledge	• Introductory courses to Chemistry • Attendance of the compulsory elective module *Specialization (Macro)Molecular Engineering*
Requirements of the assignment of credits	• For lectures: Written exam at the end of the semester • For seminars: Presentation of a topic + participation in discussion • For practicals: Written report

3.6.4 Physics of Molecular Systems Science and Engineering

CODE: MSSE_PMSSE	TITLE: **Physics of Molecular Systems Science and Engineering**
Type	• Compulsory elective module of the section MSSE_Core-III • Dependent on student's course selection
Credit Points	6
Workload	180 hours
Term	ST
Module parts and teaching methods	Students select lectures and/or seminars to a total of 6 CP according to their preferences and availability.
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to… … understand advanced physical principles of molecular systems. … demonstrate insight into the physical characterization of molecular systems and their fabrication. … demonstrate insight into the applications of molecular systems in the physical sciences.
Content	• Advanced methods in micro- and nanotechnology, and/or computation and/or spectroscopy • Physics of Molecular Systems • Applications
Prerequisites	None
Recommended knowledge	Introductory courses to physics
Requirements of the assignment of credits	• For lectures: Written exam at the end of the semester • For seminars: Presentation of a topic + participation in discussion • For practicals: Written report

3.7 Scientific Specialization

CODE: MSSE_SciSpec	TITLE: **Scientific Specialization**
Type	• Compulsory module • 12-week lab practical
Credit Points	15
Workload	450 hours
Term	WT
Module parts and teaching methods	Lab rotation in preparation for the Master Thesis
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to… … demonstrate advanced knowledge in the research field of the planned master thesis. … work on a project in a research laboratory under supervision.
Content	• The content of the module is defined together with the supervisor and will vary depending on the chosen research field in which the master thesis is planned. • In addition to the work within the research group may comprise specified lectures, seminars, or journal clubs as well as a substantial part of self-study.

Prerequisites	• Successful completion of the following modules and sections:
	  ○ MSSE_Core-I
	  ○ MSSE_Core-II
	  ○ MSSE_CSLab
	• Overall, 42 CP need to have be completed.

Recommended knowledge	Suggested by supervisor
Requirements of the assignment of credits	• Oral examination on the content of the module • Written lab report

3.8 Methods and Project Planning

CODE: MSSE_MPP	TITLE: **Methods and Project Planning**
Type	• Compulsory module • 12-week lab practical
Credit Points	15
Workload	450 hours
Term	WT
Module parts and teaching methods	• Work within a research group under supervision of the group leader • To pass this module, the student has to be part of a research group. • Upon completion of this course, the student is well prepared for the master thesis.
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to… … demonstrate advanced knowledge in the research field of the planned master thesis. … work on a project in a research laboratory under supervision.
Content	• The content of the module is defined together with the supervisor and will vary depending on the chosen research field in which the master thesis is planned. • In addition to the work within the research group may comprise specified lectures, seminars, or journal clubs as well as a substantial part of self-study.

Prerequisites	• Successful completion of the following modules and sections:
	  ○ MSSE_Core-I
	  ○ MSSE_Core-II
	  ○ CSLab
	• Overall, 42 CP need to have be completed.

Recommended knowledge	Suggested by supervisor
Requirements of the assignment of credits	• Oral examination on the content of the module • Written lab report

3.9 Master Thesis (including colloquium)

CODE: MSSE_MTC	TITLE: **Master Thesis (including colloquium)**
Type	• Compulsory module • 6-month lab practical
Credit Points	30
Workload	900 hours
Term	ST
Module parts and teaching methods	Master thesis and oral examination (colloquium)
Application of the module	Molecular Systems Science Engineering (Master of Science)
Objectives	At the end of the module, the students will be able to… … develop a hypothesis and will be able to plan and analyze the necessary experiments to test it. … perform scientific research in a research laboratory. … pursue a successful career in academia or industry.
Content	• Research work on a specific MSSE-related topic. • Work within a research group under supervision of the group leader.
Prerequisites	• advanced knowledge on the research area of the master thesis • MSSE_SciSpec compulsory module must be completed • MSSE_MPP compulsory module must be completed
Recommended knowledge	Suggested by supervisor
Requirements of the assignment of credits	• Written master thesis. • Colloquium: The results of the Master's thesis are presented and defended in an oral examination (colloquium). The colloquium is held in front of two examiners. It lasts approximately 40-60 minutes.